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Optical identification of sources from the HELLAS2XMM survey

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Abstract. We present preliminary results on the optical identifications of sources from the High Energy Large Area Survey performed with XMM-Newton (HELLAS2XMM). This survey covers about 3 square degrees of sky down to a 2-10 keV flux of 7×10^{-15} erg cm^{-2} s^{-1} (Baldi & Molendi these proceedings, Baldi et al. 2001). The survey good sensitivity over a large area allows us to confirm and extend previous Chandra results about a population of X-ray luminous but optically dull galaxies emerging at 2-10 keV fluxes of $\approx 10^{-14}$ erg cm^{-2} s^{-1}. Although the statistics are still rather poor, it appears that at these X-ray fluxes the fraction of these galaxies is similar or even higher than that of narrow line AGN.

1. Introduction

Thanks to their revolutionary capabilities (i.e. arcsec quality imaging, implying a position reconstruction better than a few arcsec, and large throughput), Chandra and XMM-Newton have opened up a new volume of discovery space: a factor 50 increase in sensitivity in the 2-10 keV hard X-ray range. The deep surveys performed so far cover only a small field of view: a quarter of a square

degree for the Chandra surveys and a similar area for the XMM-Newton Lockman hole survey. Our approach is complementary to these deep pencil beam surveys in that we plan to cover a different portion of the redshift–luminosity plane. Our purpose is to study cosmic source populations at fluxes where a large fraction of the hard X-ray Cosmic background (HXRB) is resolved ($\approx 50\%$ at $F_{2-10} > 10^{-14}$ erg cm^{-2} s^{-1} , see e.g. Comastri et al. 1995, 2001), but where a) the area covered is as large as possible, to be able to find sizeable samples of "rare" objects; b) the X-ray flux is high enough to provide at least rough X-ray spectral information; and c) the magnitude of the optical counterparts is bright enough to allow, at least in the majority of the cases, relatively high quality optical spectroscopy, useful to investigate the physics of the sources.

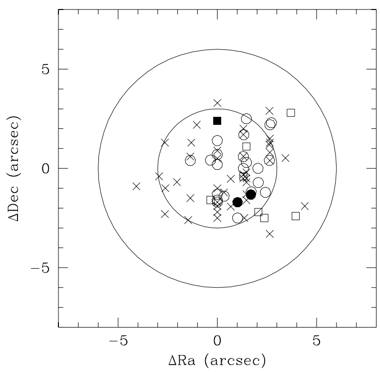
Our goal is to evaluate for the first time the luminosity function of hard X-ray selected sources in wide luminosity and redshift ranges. By integrating this luminosity function we will compute the hard X-ray luminosity density per unit volume due to accretion as a function of the redshift. This will then be compared with the history of the UV luminosity density (proportional to the history of the star-formation) and to the prediction of models for the evolution of structures in the universe (following the scheme proposed by e.g. Fontana et al. 1999). This may give us a clue on the correlations between formation and evolution of AGN and supermassive black holes and formation and evolution of galaxies.

We report here on the preliminary results of the optical identification of hard (2-10 keV) X-ray sources from a 3 square degree survey performed using XMM-Newton public fields (HELLAS2XMM Baldi & Molendi these proceedings, Baldi et al. 2001). We compare these results with those obtained by our collaboration using Chandra fields and with the result of Chandra pencil beam deep surveys (HDFN, Hornschemeier et al. 2001, SSA13, Barger et al. 2001 and CDFS, Giacconi et al. 2001, Tozzi et al. 2001, Norman et al. 2001).

2. X-ray data and optical identifications

During the last year we have obtained optical spectroscopic identification of hard (2-10 keV) X-ray selected sources discovered in 5 Chandra fields (Fiore et al. 2000, Cappi et al. 2001). We are now complementing our medium deep survey with 15 XMM-Newton fields (Baldi et al. 2001), for a total of 3 deg^2 of sky surveyed at a 2-10 keV flux limit of about 10^{-14} erg cm^{-2} s^{-1} . 495 sources have been detected in the 2-10 keV band (at a threshold probability of 2×10^{-5}, see Baldi et al. (2001).

Four of the 15 XMM-Newton fields (in addition to the Lockman hole, Hasinger et al. 2001) have been followed-up in the optical band so far using the ESO 3.6m and the TNG telescopes (the PKS0312-77, PKS0537-28, Abell2690 and G158-100 fields). In the following we concentrate on the results obtained for the 115 sources detected in these four fields. Their 2-10 keV fluxes range between 7.7×10^{-15} and 10^{-13} erg cm^{-2} s^{-1} . 24 sources (20%) have $F_{2-10keV} \gtrsim 5\times10^{-14}$ erg cm^{-2} s^{-1} . Sources with these fluxes should provide spectra with $\gtrsim$ a few hundred counts in relatively short ($\sim$ 10ks) XMM-Newton observations. Accurate information on their spectral shape is therefore either already available or it can be obtained in the near future. We note that 5×10^{-14} erg cm^{-2} s^{-1} is



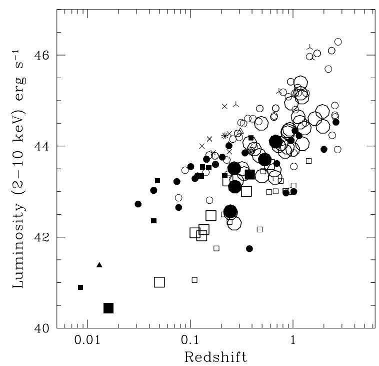


Figure 1. left: The deviation in RA and dec between the XMM-Newton positions and the position of the nearest optical source. Figure 2. right: The luminosity-redshift diagram for the HELLAS2XMM sources (big symbols); the BeppoSAX HELLAS sources (smaller symbols at lower redshifts); and the Chandra SSA13 and HDFN deep surveys (smaller symbols at higher redshifts, data from Barger et al. 2001). In both diagrams different symbols identify different source classes: Open circles = broad line, quasars and Sy1; filled circles = narrow line AGN; filled squares = starburst galaxies and LINERS; open squares = optically 'normal' galaxies; stars = clusters of galaxies; open triangles = radio loud quasars; skeleton triangles = BL Lacertae objects. In the left panel crosses mark unidentified sources.

also the flux limit of the BeppoSAX HELLAS survey, and therefore "all" HELLAS sources are well suited for X-ray follow-up. Conversely, no source from the deep, pencil beam surveys performed by Chandra has a 2-10 keV flux higher that this limit. The X-ray follow-up of the faint Chandra sources must await high throughput missions like Constellation X and XEUS.

We have deep R band images for 86 (75%) of the 115 HELLAS2XMM X-ray sources. We found optical counterparts brighter than R=24.5 within 5" from the X-ray position in 75 cases (actually within 3" in most of these cases, see figure 1). 11 sources (about 13%) have R$\gtrsim$24.5. For one fourth of the sources in the sample (34 sources) we have already obtained spectra in an ESO 3.6m run performed on Dec. 2000. This sample can be combined with previous works based on Chandra 2-10 keV detections (see Fiore et al. 2001 and references therein). Five of the seventeen Chandra sources with redshifts are common to the XMM sample. Therefore the total number of hard X-ray selected sources with optical spectroscopy is at the moment 46. This is one of the largest sample of faint hard X-ray selected sources with redshifts (see figure 2, which shows the $L_{2-10keV}$–redshift diagram for these sources and other hard X-ray selected

samples). We expect to increase the optical identifications in two 3.6m and 1 TNG runs already scheduled for the second half of 2001.

2.1. Source breakdown

The source breakdown is intriguing: while about half of the sources are normal broad line quasars, the other half is quite varied: there are X-ray obscured, emission line AGN, starburst galaxies and, most unusually, X-ray luminous but apparently "normal" galaxy at $0.05 < z < 0.35$ (8 out of 46). Their X-ray luminosity, in the range $10^{42} - 2 \times 10^{43}$ erg s^{-1}, is 10-100 times higher than that predicted based on their optical luminosity, and similar to that of Seyfert 1 galaxies. Their X-ray count ratios indicate a hard X-ray spectrum in many of them. All this strongly suggests an (obscured) AGN in these objects (see Comastri et al. these proceedings and Fiore et al. 2001 for a more detailed discussion on one of these objects). Possibly obscured AGN emission lines could be overshined either by the stellar continuum or by a nuclear non thermal continuum. Alternatively, they could be not efficiently produced. Interestingly, the fraction of narrow line AGN (5 out 46) is smaller than that of X-ray loud, optically dull galaxies. A similar result has been recently published by Barger et al. (2001), based on deep Chandra surveys. Both increasing the sample of these objects and sensitive multifrequency follow-ups are clearly crucial to discriminate among competing possibilities. The AGN populating hard X-ray surveys may span ranges of X-ray and optical properties wider than previously thought, with important consequences for the evaluation of the total 'accretion luminosity' of the Universe (see e.g. Iwasawa & Fabian 1999).

2.2. X-ray to optical ratios

We have found in our photometric observations that 65% of the X-ray sources have a counterpart brighter than R=22, 23% have 22 $<$R$<$ 24.5 and 12% have R$>$ 24.5. It will not be probably feasible to obtain redshifts for the latter faint sources through optical spectroscopy. The remaining alternatives are a) to obtain redshift directly from the X-ray spectra (Baldi et al. 2001b in preparation); and b) to obtain approximate redshift through multicolor optical and near infrared photometry.

Figure 3 shows the X-ray to optical flux ratio of the XMM sources as a function of the X-ray flux. This is compared with the analogous ratios for the sources from the Chandra SSA13 and HDF-N deep pencil beam surveys. Solid lines show loci of constant R magnitude. We note that while the fraction of sources with R$\gtrsim$24.5 will be higher in the deep surveys, their X-flux will be smaller (by a factor of typically 10) and therefore it will be difficult to obtain their redshift through optical and/or X-ray spectroscopy. This means that a relatively large fraction of sources from deep surveys will remain unidentified, at least until the advent of the next generation of optical and infrared large telescopes (NGST from the space and the 30m[1] and 100m[2] telescopes from the

[1] see e.g. http://staging.noao.edu/gsmt.html

[2] http://www.eso.org/projects/owl/

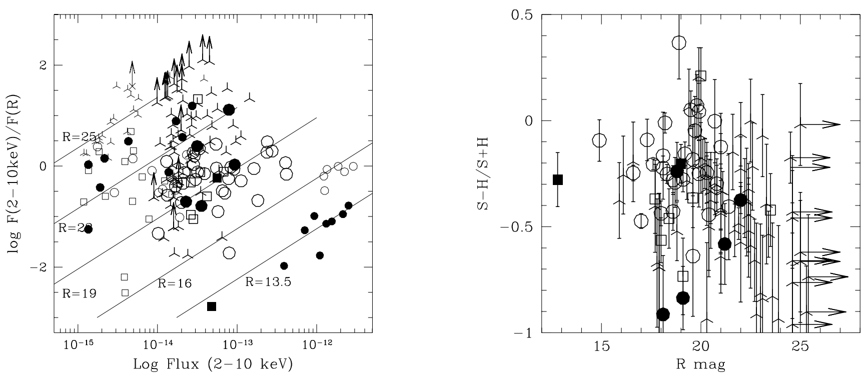


Figure 3. left: the ratio between the X-ray (2-10 keV) and optical (R band) fluxes for the HELLAS2XMM sources (big symbols), the sources from the SSA13 and HDF-N deep surveys (data from Barger et al. 2001 and Hornschemeier et al. 2001, small symbols at low fluxes) and two samples of optically selected AGN: PG quasars and Compton thin Seyfert 2 galaxies (small symbols at high fluxes). Symbols as in Figure 1 and 2; skeleton triangles mark unidentified sources. Figure 4. right: The X-ray softness ratio (S-H)/(S+H) (S=0.5-2keV flux; H=2-10 keV flux) as a function of the R band magnitude for the HELLAS2XMM sources

ground, Gilmozzi & Dierickx 2000 and references therein). Conversely, the X-ray fluxes of the XMM 3 degrees survey are high enough to try to search for iron and oxygen features which in turn could provide redshifts.

Figure 4 shows the X-ray softness ratio as a function of the R band magnitude. The figure shows clearly that soft sources tend to have brighter R magnitudes. The average magnitude of the sources with ((S-H)/(S+H)> -0.3) is 19.8 with a dispersion of 2.1, while the average magnitude of the sources with ((S-H)/(S+H)< -0.3) is 21.5 with a dispersion of 2.2. The optical counterparts of most soft sources is brighter than R$\lesssim$23, bright enough to measure the redshift and in turn to evaluate the accretion luminosity. Conversely, a relatively large fraction of hard sources have R$\gtrsim$24.5. As mentioned above for many of them it will be difficult to obtain a redshift and so to estimate the luminosity. It will therefore be difficult, if not impossible, to localize the redshift from which the accretion power of these sources is coming and to measure it, using optical spectroscopy. For the brighter X-ray sources the redshift could be estimated directly from the X-ray spectrum. This will be unfeasible for the faint hard sources discovered in deep and ultradeep surveys. This means that deep pencil beam surveys are probably less efficient to depict the history of the accretion in the Universe than shallower and larger area surveys like the HELLAS2XMM survey.

Figure 3 also illustrate the efficiency of X-ray surveys in probing accretion (as also often remarked by R. Mushotzky). At a 2-10 keV flux of, say, 10^{-14} erg cm^{-2} s^{-1} there are 300–400 sources per square degree (see Baldi et al. these proceedings and references therein). Optically selected AGN have a 2-10 keV to R band flux ratio of at most 1 (PG quasars, see figure 3), and therefore their R band magnitude at $F_{2-10keV} = 10^{-14}$ erg cm^{-2} s^{-1} is R$\lesssim$21. The number of optically selected AGN at these magnitudes is 100-150 per square degree, a factor 2-3 less than hard X-ray selected AGN (also see La Franca et al. these proceedings). To reach an AGN surface density of $\sim$ 300 deg^2 optical surveys must be pushed down to B=23.5, where contamination from compact emission line galaxies is very large, making the optical spectroscopic follow-up much less efficient than for X-ray surveys (Mignoli & Zamorani 2001 in preparation).

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